ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
FY11 Project Description

REDOUBT VOLCANO: EDIFICE AND 2009 DOME GEOLOGIC INVESTIGATIONS

In 2008 the Alaska Volcano Observatory (AVO), led by the Division of Geological & Geophysical Surveys (DGGS), initiated efforts to produce an updated geologic map and hazard assessment of Redoubt volcano. Those efforts were interrupted by the onset of Redoubt's eruption on March 15, 2009, following 19 years of repose. Most efforts of DGGS's Volcanology Section, as well as other AVO agencies, were redirected to eruption response. The eruption waned during the late spring of 2009, and by summer 2010 work on the map and hazard assessment could resume—coupled with work on the deposits and effects of the 2009 eruption.

Activities and Results: During the 2010 field season DGGS-AVO geologists successfully completed fieldwork on Redoubt Volcano with three goals: (1) to further completion of the geologic map of Redoubt Volcano begun in 2008; (2) to sample and study the 2009 lava dome; and (3) to further describe 2009 deposits. Fieldwork to improve the geologic map entailed detailed mapping of lava flows that had been successfully dated by collaborating researchers with the U.S. Geological Survey. Early Holocene ages of flow that were thought to be older (Pleistocene) drove a reinvestigation and reinterpretation of the morphology of those flows. Dome sampling was complicated by its altitude (~8,000 feet), active fumaroles, and the potential of instability. Yet well located samples of the dome are required for investigations of the dome building process. One sampling method utilized a small dredge towed by the helicopter (fig. 1), a technique pioneered by the USGS Cascades Volcano Observatory (CVO) as a way to sample the Mt. St. Helens dome in Washington. Other samples were collected by hand during extremely brief landings. Vesicularity studies are in progress on the retrieved samples, and further chemical analyses are pending. AVO-DGGS geologists also collaborated with researchers from Cold Regions Research & Engineering Laboratories (CRREL), U.S. Army Corps of Engineers, in an attempt to acquire high-resolution ground-based LiDAR imaging of the dome surface; ultimately weather precluded data acquisition.

Products: AVO-DGGS geologists presented the ongoing research into the growth and morphology of the 2009 Redoubt Volcano lava dome at the annual American Geophysical Union conference in San Francisco in December 2010. AVO, CVO-USGS, and University of Northern Colorado colleagues are drafting a paper on dome growth and morphologic changes as part of a special issue on the 2009 eruption of Redoubt volcano to be published in the *Journal of Volcanology and Geophysical Research.* Completion of the map awaits further geochemical and age data.

Figure 1. Photograph showing helicopter (arrow) dredge-sampling the 2009 lava dome in the crater of Redoubt volcano. (Photo by Steven Anderson, University of Northern Colorado).

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REDOUBT VOLCANO:
TEPHRA STUDIES

In March 2009, after nearly 19 years of quiescence, Cook Inlet's ice-covered Redoubt volcano began erupting explosively. Over the course of three weeks, at least 19 explosions sent ash into the atmosphere to heights between 5 and 19 kilometers (17,000 to 62,000 feet) above sea level (ASL), resulting in tephra fallout throughout south-central Alaska, affecting an area of ~80,000 square kilometers. Tephra is the fragmental material of varying particle size produced by volcanic explosions; it consists of pulverized rock, glass, and crystal fragments. Volcanic ash is tephra with a particle size of less than 2 mm in diameter, and is the most significant volcanic hazard to humans, machinery, and the environment owing to its wide dispersal by wind.

In spring 2009, Division of Geological & Geophysical Surveys (DGGS) geologist Janet Schaefer, along with U.S. Geological Survey (USGS) colleague Kristi Wallace, both of the Alaska Volcano Observatory, mapped, sampled, and described the 2009 Redoubt tephra deposits. Throughout the course of the year, more than 200 samples were processed in the lab. By analyzing tephra fallout patterns using NEXRAD radar data and interpreting dozens of stratigraphic sections, the geologists constructed a contour map of tephra fall density (fig. 1). A total tephra-fall volume (dense-rock equivalent) for all 19 explosions is estimated to be 22.6 million cubic meters with a single event maximum of ~6 million cubic meters. These estimates are comparable to previous historical eruptions of Redoubt volcano and are an indication of its eruptive power and continuing widespread ash impacts.

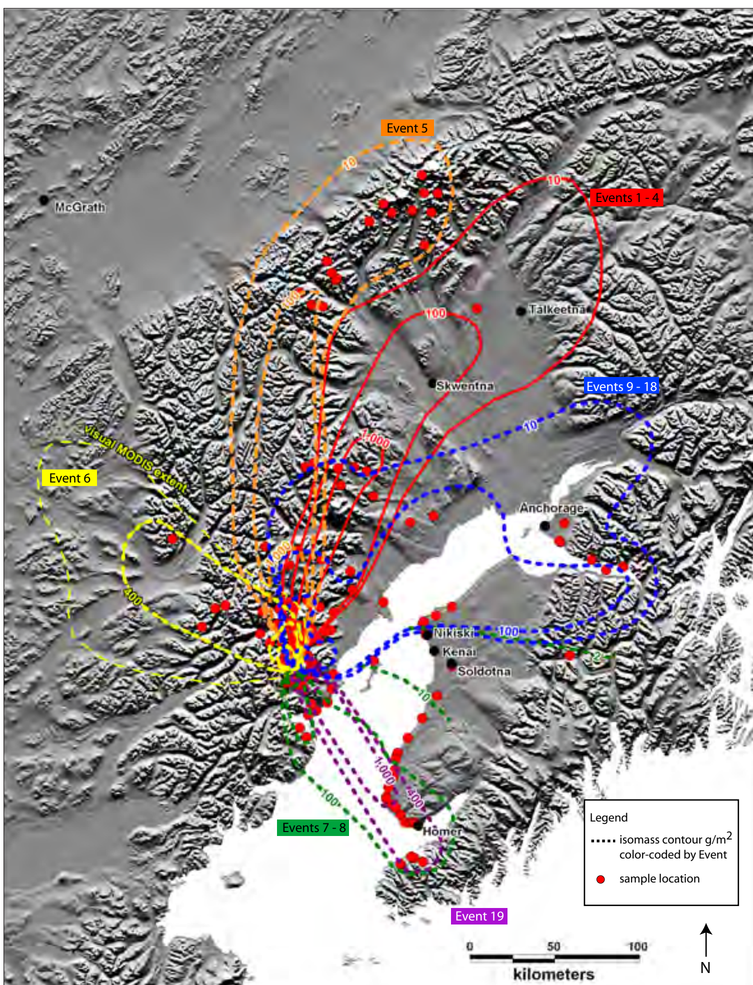

Figure 1. Map showing isomass contours of tephra-fall deposits from the 2009 eruption of Redoubt volcano. Outer contour is 10 grams per square meter, however, trace ash fall (<0.8 mm thick) extended beyond these contours, as far as Fairbanks, 550 kilometers to the north–northeast of the volcano.

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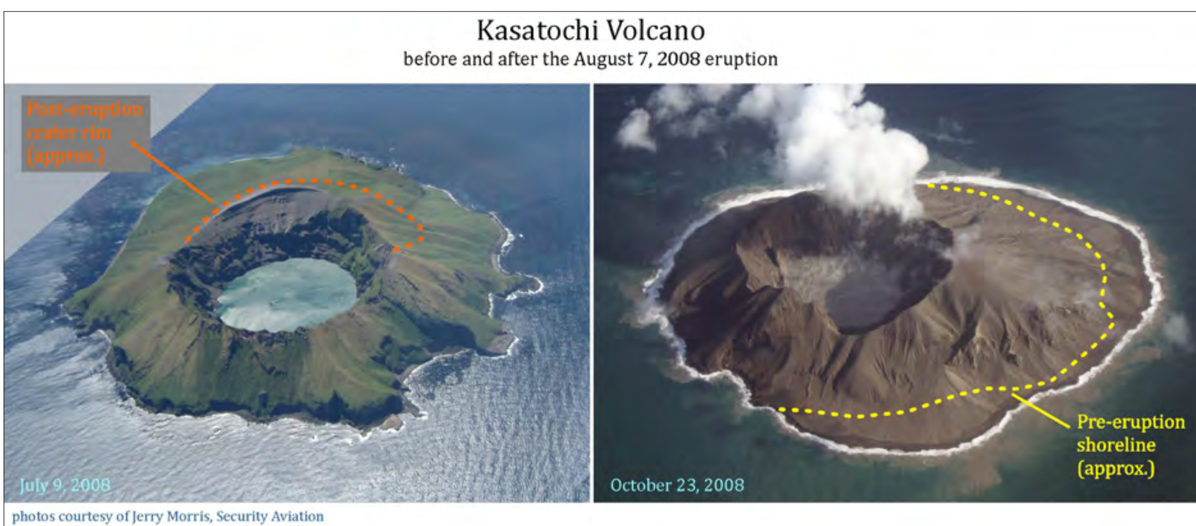
ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
FY11 Project Description

KASATOCHI VOLCANO:
GEOLOGIC STUDIES AND ECOSYSTEM RESPONSE

The August 7, 2008, eruption of Kasatochi volcano, located near Adak in the Aleutian Islands, was short, powerful, and came with little warning. Over the course of about 24 hours a series of explosive eruptions produced pyroclastic flows that swept all sides of the tiny island, building new beaches some 400 meters seaward and leaving deposits more than 10 meters thick. Additionally, the explosions enlarged the 1,100-meter-diameter summit crater by more than 250 meters. Ash clouds reached the stratosphere and were carried rapidly to the east, disrupting air traffic to Alaska and along the North Pacific air route. The ash clouds ultimately circled the globe, producing vibrant sunsets in the 'Lower 48' states. The eruption was preceded by a short (36-hour), yet exceptionally intense, earthquake swarm, with more than a thousand earthquakes greater than 2 in magnitude (M), the largest of which was M 5.7. Kasatochi had not erupted for at least a century, and perhaps not during the 250 years of recorded history in Alaska.

Despite its small size—some 2.5 kilometers in diameter—Kasatochi previously supported a lush ecosystem, and that ecosystem was devastated by the eruption. Of particular concern were the auklet nesting colonies because Kasatochi was among only a dozen or so auklet nesting sites in the north Pacific, and auklets rely on existing rock crevices for nesting. Kasatochi also presented a rare opportunity to study the recovery of an island ecosystem that had been well described before the devastation. A multidisciplinary study of ecosystem recovery began in 2009, funded by the North Pacific Research Board, the USGS, and the U.S. Fish and Wildlife Service. Studies in 2009 documented that no chicks of any bird species successfully fledged, compared to ~50,000 birds that fledged in 2008; the investigations also found that, surprisingly, root mats of the pre-eruption vegetation were not all destroyed, and in some of the rare places where erosion had revealed the 2008 surface, plants now grew.

As part of the interdisciplinary project, the Division of Geological & Geophysical Surveys (DGGS) is heading efforts to produce the first geologic map of the island and to investigate the older lava and tephra units on the island. About 12 days total field time in four trips (two in 2009 and two in 2010) have resulted in identification of general stratigraphic units and a full suite of rock samples. Products of Alaska Volcano Observatory work at Kasatochi to date include numerous presentations at an American Geophysical Union special session, special editions of two major journals devoted to the eruption, and several articles in Alaska newspapers. Completion of the geologic map, anticipated in fall 2011, awaits further analytical data on sample age and composition. Support for this project (from 2010 and ongoing) is from the American Reinvestment and Recovery Act through a cooperative agreement between USGS and DGGS.



Oblique aerial photographs of Kasatochi before and after the eruption—both taken during 2008, but from different directions. Pyroclastic flows have built fans that cover previous beach bluffs and extend the shoreline up to 400 meters. In addition, the post-eruption crater is significantly larger. Both photographs are courtesy of Jerry Morris, Security Aviation

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OKMOK VOLCANO: GEOMORPHOLOGY AND HYDROGEOLOGY OF THE 2008 PHREATOMAGMATIC ERUPTION

On July 12, 2008, with less than 5 hours of precursory seismic activity, the central Aleutian volcano Okmok erupted explosively, marking the beginning of a 5-week-long eruption that dramatically changed the morphology and groundwater system in the 8-kilometer-wide caldera. The initial explosion sent an ash- and gas-rich column to 15 kilometers above sea level. Early in the eruption, heavy rain mixed with new tephra on the flanks of the volcano, generating lahars (volcanic mudflows) that traveled across the upper slopes of the volcano and down all major drainages, creating large new deltas along the shoreline. For the next 5 weeks, eruption intensity waxed and waned with explosions occurring from multiple vents on the caldera floor as rising magma interacted with shallow groundwater. One crater formed next to, and eventually captured and drained, the largest pre-existing caldera lake (total volume drained was 13.6 million cubic meters). As the eruption subsided, coalescing maar and collapse craters eventually filled with water, forming a new lake to the west of cone D (fig. 1a) and dramatically changing the morphology and volume of the old lake (fig. 1b). The longest-lived vent formed a 250–300-meter-high, ~1.5-kilometer-wide tuff cone on the western flank of pre-existing cone D. This new tuff cone, the new lakes and collapse pits, and the accumulation of many tens of meters of fine-grained tephra have significantly altered the Okmok landscape. This eruption was substantially larger than any Okmok eruption since that of 1817 (which destroyed the then-unoccupied village of Egorkovskoe on the north coast of Umnak) and far larger than the eruptions of 1945, 1958, or 1997.

Division of Geological & Geophysical Surveys (DGGS) Geologist Janet Schaefer, along with Alaska Volcano Observatory (AVO) and Northern Arizona University (NAU) scientists, visited Okmok in the summer of 2010 to investigate and document this fascinating eruption, the first phreatomagmatic event (explosive eruption caused by contact between rising magma and groundwater) to occur in the United States since the 1977 eruption of Ukinrek Maars on the Alaska Peninsula. Fieldwork focused on the stratigraphy and sedimentology of the tephra deposits from the 2008 eruption, documentation and description of vent evolution, a revision of the hazard assessment, and the creation of a post-eruptive geologic map. A summary of the stratigraphy and sedimentology of the 2008 tephra deposits was presented at the 2010 Fall meeting of the American Geophysical Union. The revised hazard map and geologic map are anticipated to be completed within 2 years.

Figure 1. (a) Oblique aerial view, looking east, of Okmok caldera showing the new tuff cone, explosion craters, lakes, and a field of collapse pits adjacent to Cone D. (b) Post-eruption satellite image annotated to show the pre-eruption lakeshore (in blue) of "old" Cone D lake, the pre-eruption bathymetry (in yellow), and the expanded post-eruption lake, north of cone D. North is up.

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CHIGINAGAK VOLCANO: MONITORING ENVIRONMENTAL RECOVERY FROM THE 2005 ACID CRATER LAKE DRAINAGE

Mount Chiginagak is a hydrothermally active volcano on the Alaska Peninsula, approximately 170 kilometers (100 miles) south–southwest of King Salmon. Sometime between November 2004 and May 2005, a 400-meter-wide (~1,300-foot-wide), 100-meter-deep (~330-foot-deep) lake developed in the formerly snow- and-ice-filled crater of the volcano. In early May 2005, an estimated 3 million cubic meters (106 million cubic feet) of sulfurous, clay-rich debris and acidic water exited the crater through tunnels in the base of a glacier that breached the south crater rim. More than 27 kilometers (17 miles) downstream, the acidic waters of the flood reached approximately 1.3 meters (4 feet) above current water levels and inundated an important salmon spawning drainage, acidifying Mother Goose Lake from surface to depth (pH of 2.90 to 3.06) and preventing the annual salmon run in the King Salmon River. A release of caustic gas and acidic aerosols from the crater accompanied the mud flow and flood, causing widespread vegetation damage along the flow path. An interdisciplinary science team led by the Division of Geological & Geophysical Surveys (DGGS) has been monitoring the status of the remaining crater-lake water that continues to flow into Mother Goose Lake.

Beginning in 2009, an ice layer began to reform in the crater lake, indicating a cessation in the crater's fumarolic heat source (fig. 1). Despite the newly reformed ice layer, more than 1 million cubic meters (35 million cubic feet) of water remains in the crater and continues to supply acidic water to Mother Goose Lake and the King Salmon River.

In August and September 2010, DGGS conducted fieldwork with U.S. Fish & Wildlife Service (USFWS) fisheries biologists, sampling water and investigating the recovery of fish in the acidified system. Biologists found that a variety of salmon species had returned to Mother Goose Lake in 2010, and pH measurements confirmed that the acidity of the lake had declined (pH increase from 4.8 in 2009 to 5.4 in 2010) creating more habitable conditions for the fish. If the current trend continues, the pH of Mother Goose Lake should approach a normal range by the end of 2012.

Geologic Mapping and Volcano Hazard Assessment

The DGGS-led geologic mapping and hazard assessment fieldwork that began in 2004 was completed in 2008. Investigations have revealed a long history of hydrothermal activity, debris avalanches, and lava flows at the volcano. A geologic map and volcano hazard assessment are scheduled to be published by DGGS in 2011. This work has been supported by the USFWS.

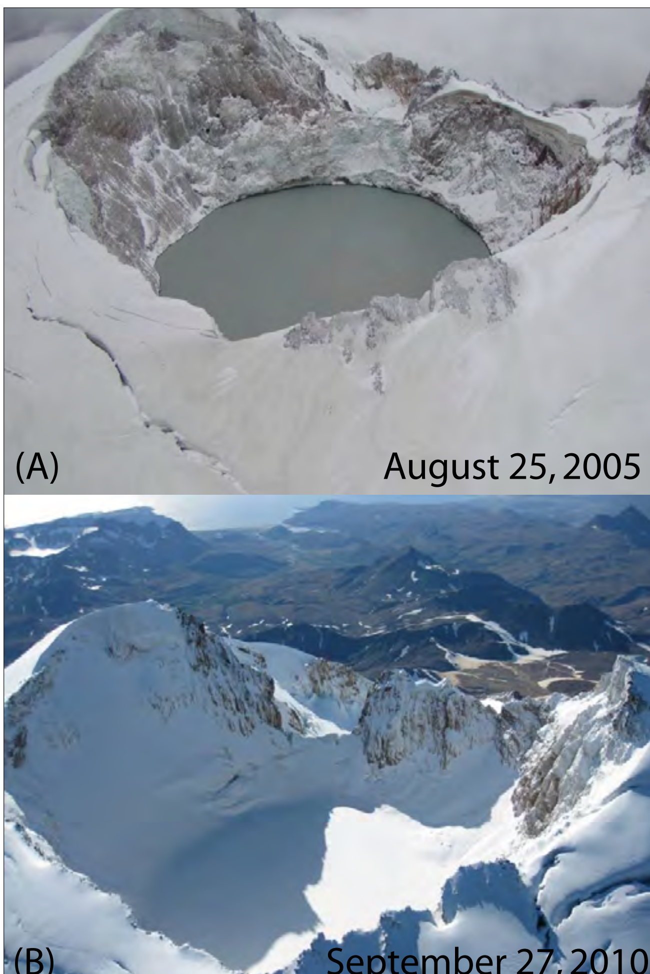

Figure 1. (A) The summit crater lake at Chiginagak volcano in August 2005, ~3-1/2 months after the crater lake partially drained, and (B) September 27, 2010. Snow and ice are once again accumulating in the crater as the glacier reforms in response to the cessation of heat flow to the summit. Photos by Janet Schaefer, DGGS.

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ALASKA VOLCANO OBSERVATORY WEBSITE AND DATABASE

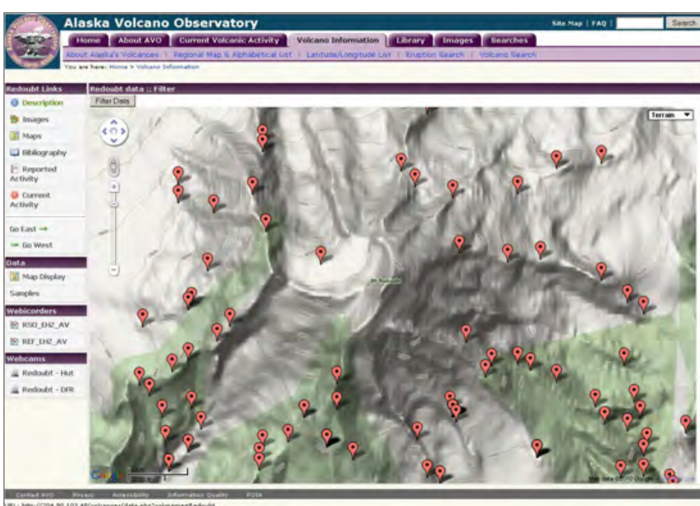
The Alaska Volcano Observatory (AVO) public website (http:www.avo.alaska.edu) serves about 2,800,000 pages and approximately 300 gigabytes of data to well over 100,000 unique visitors per month, and is among the top ten U.S. Geological Survey (USGS) and USGS-affiliated websites in the country. It continues to be the most complete single resource on Quaternary volcanism in Alaska. The Division of Geological & Geophysical Surveys (DGGS) was the original creator of the AVO website in 1994, and continues to be the site designer, builder, and manager.

During FY2010, supported by American Recovery and Reinvestment Act (ARRA) funding, three new servers were purchased and added to AVO's web-serving configuration. In the previous server configuration, one server hosted both the database and website, with a backup server doing the same. Serving both the website and database is a resource-intensive task, especially during episodes of eruptive activity. An average day's traffic generates 100,000 page views and 3,000,000 queries on the database. These numbers can expand exponentially during an eruption, made clear by how the AVO webservers were briefly unable to handle the traffic during the Redoubt unrest in January 2009. In the new configuration, the webserver and database server are separately installed on two of the new servers (in addition to the two older servers that each contain both the website and the database). The third new server will store and host GIS data about Alaska's volcanoes.

The three database servers are also configured in a multi-master replication scheme. This type of replication allows users to enter data on any database server; that data will then be available on any other server. This creates instant data redundancy; should any server fail due to load or hardware/software issues, traffic can be redirected to another server.

AVO's website content is dynamically queried from a MySQL database named GeoDIVA (Geologic Database of Information on Volcanoes in Alaska). GeoDIVA maintains complete, flexible, timely, and accurate geologic and geographic information on Pleistocene and younger Alaska volcanoes to assist scientific investigations, crisis response, and public information. GeoDIVA is currently the most comphrensive and up-to-date authoritative source for information on Alaska volcanoes. It is still under construction, in a modular format. As modules are completed, they undergo continual maintenance so that they remain timely and useful. Current modules in maintenance mode include: bibliography (4,450+ references); basic volcano information (~140 major and ~200 minor volcanic features, 52 'historically active'); eruption history (information, text, and references for more than 430 historic eruptions); images (>18,300); sample information (~7,100); hand sample storage (>15,000); and vent count (~1,200 vents). Modules in continuing development and initial data-load stages include geochemistry (~3,000 analyses, ~113,000 records); petrology (~90 1,000-point point-count analyses); GIS data, geochronology, and tephrachronology/tephra impacts. AVO now owns a dedicated server for GIS data and has licenses for geospatial software. In coming months we will work to input geospatial data and metadata into the server, and make it queryable and usable for AVO staff.

Also developed during FY2009 is the public ash-reporting database and website interface. This effort was in response to the hundreds of citizen ash reports that were phoned and emailed to AVO during the 2009 eruption of Redoubt volcano—each one requiring a staff response. The initial effort was helpful to reduce the burden of citizen ash reporting on AVO staff, but had a number of shortcomings, mostly because of the rapidity of its development. In 2010, we significantly improved and refined the database. We added a map display of samples, coded by ash present/not present and verified/not verified; created a more user-friendly interface; streamlined questions to collect the data that is most important to AVO; and incorporated suggestions from the National Weather Service and global tephra experts.



AVO is on the leading edge of web and database development for volcano observatories, and is actively sharing its expertise with other observatories in the U.S. DGGS is following new and emerging technologies that will allow further enhancement of AVO's web presence and data dissemination abilities. DGGS continually refines and enhances the applications that AVO and other observatories use on a regular basis; the focus will remain on continual incremental improvements to the site, and serving new database modules as they become available.

The Redoubt volcano data map shows locations of published samples. Each marker contains links to the sample's citation information, as well as descriptive, geochemical and petrological data if they exist.

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